भारतीय मानक
Indian Standard

IS 16486 : 2017

बल-आघूर्ण रिंच टेस्टर सहित बल-आघूर्ण मापन युक्तियों के अंशशोधन एवं वर्गीकरण की पद्धति

Method for Calibration and Classification of Torque Measuring Devices including Torque Wrench Tester

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Hand Tools Sectional Committee, PGD 34

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Hand Tools Sectional Committee had been approved by the Production and General Engineering Division Council.

This standard has been formulated based on the prevalent practice followed by Indian industry. While formulating this standard considerable assistance has been derived from BS 7882 : 2008 'Method for calibration and classification of torque measuring devices'.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

METHOD FOR CALIBRATION AND CLASSIFICATION OF TORQUE MEASURING DEVICES INCLUDING TORQUE WRENCH TESTER

1 SCOPE

This standard specifies the requirements for the calibration and classification of torque measuring devices, including those used for the calibration of hand torque tools.

It describes the method of calibration, calculation of calibration result and the classification of the torque measuring device in a static mode. The information to be given on the certificate of calibration is also listed.

2 SYMBOLS AND ABBREVIATIONS

For the purpose of this standard, the following common abbreviations and symbols in addition to the other specific abbreviations given in the text shall apply.

d = Deflection
d_{oMax} = Maximum residual deflection
E_{i} = Relative error of indication
E_{it} = Relative error of interpolation
L = Scale interval
O_{a} = Overall accuracy of the device
R_{o} = Relative residual deflection
R_1 = Relative repeatability
R_2 = Relative reproducibility
R_3 = Relative reversibility
r = Resolution
T_{Min} = Lower limit of calibration
u_1 = Calibration torque uncertainty
u_2 = Reproducibility uncertainty
u_3 = Repeatability uncertainty
u_4 = Resolution uncertainty
u_5 = Residual deflection uncertainty
u_6 = Temperature uncertainty
u_7 = Error of interpolation uncertainty
u_8 = Reversibility uncertainty
u_{c} = Combined standard uncertainty
U = Expanded uncertainty

3 TERMS AND DEFINITIONS

For the purpose of this standard, the following terms and definitions shall apply.

3.1 Calibration Torque — Torque with traceability derived from national standards of mass, length and of specified uncertainty of measurement, which can be applied to the torque measuring device.

3.2 Deflection (*d*) — Algebraic difference between the indicator reading prior to the application of a torque and the indicator reading for each applied torque in a given measurement series.

NOTE — The deflection may be derived from either digital data output or visual data output.

3.3 Data Acquisition System — Electronic module that has the ability to transfer, store, amplify and filter signals from a torque measuring device. This is applicable for electronic torque measuring device (*see* Fig. 1)

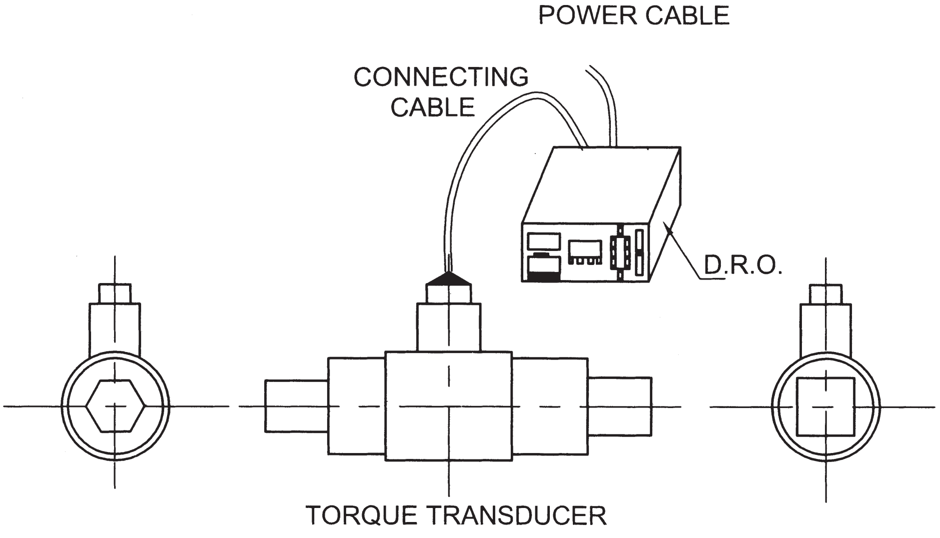


FIG.1 TORQUE TRANSDUCER (ELECTRONIC)

3.4 Loading Direction — Direction of applied torque, either clockwise or anti-clockwise about the axis of rotation, when viewed from the end of the torque measuring device to which the calibration torque is applied.

3.5 Lower Limit of Calibration (T_{Min}) — Lower value of torque at which a torque measuring device of a given class can be calibrated.

3.6 Reference Standard — Equipments used to generate or to measure the reference torque applied to the torque measuring device that is being calibrated.

3.7 Relative Error of Indication (E_i) — Mean deflection for a given value of increasing torque minus the corresponding value of applied torque.

NOTES

1 For the purpose of this Indian Standard, relative error of indication is expressed as a percentage of applied torque.

2 Relative error of indication is only used where the deflection is in units of torque.

3.8 Relative Error of Interpolation (E_{it}) — Difference between the value of the mean deflection for a given value of increasing torque and the corresponding calculated value of deflection for the given torque obtained from a mathematically fitted curve. This is applicable in case of deflection is measured in other than torque units.

NOTE — For the purpose of this standard, relative error of interpolation is expressed as a percentage of the computed deflection for the given torque.

3.9 Relative Repeatability (R_1) — Closeness of the agreement between the results of two successive measurements from the same applied torque, carried out under the same conditions of measurement.

3.10 Relative Reproducibility (R_2) — Closeness of agreement between the results of successive measurements from the same applied torque, carried out under changed conditions of measurements.

3.11 Relative Residual Deflection (R_0) — Maximum residual deflection obtained from all the series of torque.

NOTE — For the purpose of this standard, relative residual deflection is expressed as a percentage of the mean deflection for the maximum torque applied.

3.12 Difference between the deflection obtained from the last given torque series applied in an increasing mode and the deflection obtained from the last given torque applied in a decreasing mode.

NOTE — For the purpose of this standard, relative reversibility is expressed as a percentage of the deflection of the last series for the given torque, applied din an increasing mode.

3.13 Residual Deflection — Algebraic difference between the indicator readings before and after the application of a single series of torques.

3.14 Resolution (r) — Smallest discernible measurement interval on the torque measuring device indicator.

3.15 Torque — Product of tangential force and length applied about a known centre of rotation.

3.16 Torque Measuring Device — System comprising an electrical, mechanical, hydraulic or optical torque measuring device with associated instrumentation, including the automated logging of data when part of the device.

NOTE — The instrumentation can be an electronic instrument, a mechanical device, that is, a scale and pointer system, or a Bourdon tube instrument.

4 PREPARATION FOR CALIBRATION

4.1 Reference Standard

4.1.1 *Uncertainty of Calibration Torque*

Values for the maximum permissible uncertainty of the calibration torque applied for the determination of different classification of the torque measuring device shall not exceed the value given in Table 1. Where a reference standard is used to determine a calibration torque it shall conform to Table 1.

Table 1 Uncertainty of Calibration Torque

(*Clause* 4.1.1)

Sl No.	Class of Torque Measuring Device to be Calibrated	Maximum Permissible Uncertainty of Calibrations Torque Applied [1)] Percent
(1)	(2)	(3)
i)	0.05	± 0.01
ii)	0.1	± 0.02
iii)	0.2	± 0.04
iv)	0.5	± 0.10
v)	1.0	± 0.20
vi)	2.0	± 0.40
vii)	5.0	± 1.00

[1)] Using a coverage factor of $k = 2$ to give a confidence level of approximately 95 percent.

4.1.2 *Traceability of Measurements*

All definitive measurements, such as mass, length, time temperature shall be traceable to national standards, evidence of this shall be provided by a certificate of calibration.

4.2 Condition and Identification of a Torque Measuring Device

4.2.1 Condition shall not be commenced unless the torque measuring device is considered to be in good working order and is identified with a serial number. The maximum working torque shall first have been established.

NOTE — If needed the torque measuring device is adjusted or repaired prior to calibration.

4.2.2 All parts of the torque measuring device shall be identified in accordance with **4.2.1**, including the following, where applicable:

a) Signal cables,
b) Switch boxes,
c) Interfaces,
d) Data acquisition systems,
e) Computers,
f) Software (where information is available), and
g) Drive mechanism.

4.2.3 Where an electrical indicator used with a torque measuring device is replaced with another, the following requirement shall be met to ensure that the calibration is not invalidated:

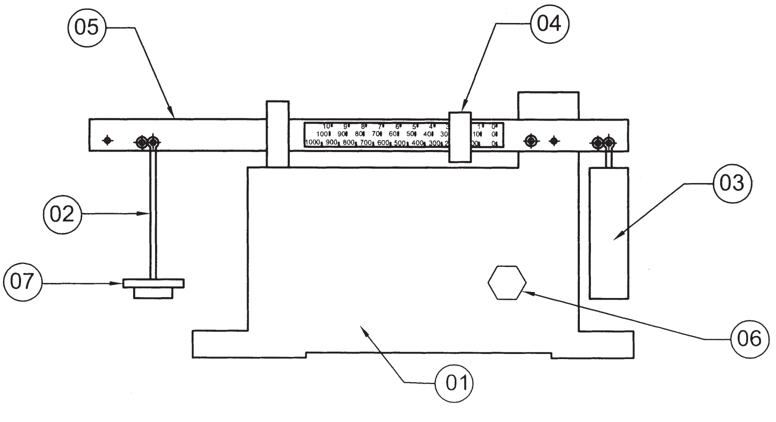
a) Original indicator shall have a valid calibration certificate, traceable to national standard that gives the results of a calibration made in terms of the units to be measured. The indicator shall have been calibrated over a range equal to or greater than the range over which it is used with the torque measuring device.
b) Replacement indicator shall have a resolution equal to or better than the indicator it is replacing and shall have a valid calibration certificate, traceable to national standard that gives the results of calibration made in terms of the units to be measured. The indicator shall have been calibrated over a range equal to or greater than the range which it is used with the torque measuring device.
c) Date of calibration on the certificate for the original shall not precede that of the certificate for the replacement indictor by more than 12 months.
d) Certificate for the two indicators show that the readings of the toque measuring device, as measured by the two indicators, agree with the value given below, over the range of the classification of the torque measuring device:
    1) ± 0.025 percent of indicated reading for a class 0.05 device;
    2) ± 0.050 percent of indicated reading for a class 0.1 device;
    3) ± 0.10 percent of indicated reading for a class 0.2 device;
    4) ± 0.25percent of indicated reading for a class 0.5 device;
    5) ± 0.50percent of indicated reading for a class 1.0 device;
    6) ± 1.00percent of indicated reading for a class 2.0 device; and
    7) ± 2.50percent of indicated reading for a class 5.0 device.
e) If it is necessary to replace cables, the replacement cables shall be of the same specification as the originals to ensure that the calibration remains valid.

4.3 Resolution of the Indicator

An indicator can be a direct reading display or the output of a data acquisition system.

4.3.1 *Mechanical Scale*

The output of the torque measuring device is measured by predefined mechanical scale (*see* Fig. 2) with slider on it, the resolution $r = ½ L$, is determined based on scale interval 'L'.



01	MAIN CASTING
02	DRIVE SHAFT
03	DEAD WEIGHT
04	SLIDING WEIGHT
05	SCALE
06	CRADLE
07	COUNTER WEIGHT
7A	100N - 2 NOS.
7B	200 N - 1 NO.
7C	500 N - 3 NOS.

FIG. 2 MECHANICAL TORQUE WRENCH TESTER — DRIVE SHAFT

4.3.2 *Analogue Scale*

4.3.2.1 When the output of the torque measuring device is measured by an indicator with an analogue scale, that is, a dial gauge or Bourdon tube instrument (*see* Fig. 3), the resolution shall be determined form the ratios between the width of the pointer and the centre-to-centre distance between two adjacent scale graduation marks (scale interval).

NOTE — The ratios should be 1/2, 1/5 or 1/10.

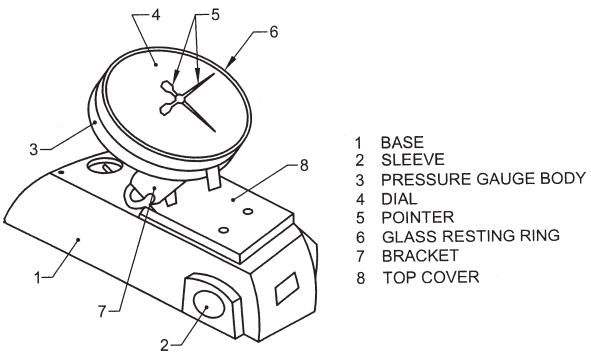


FIG. 3 STATIC TORQUE METER (HYDRAULIC)

4.3.2.2 A spacing of at least 1.25 mm shall be used for the estimation of a tenth of the division on the scale.

4.3.2.3 When using an optical recognition system, that is video, the video frame rate shall be at least 10 times the display update being recorded.

4.3.2.4 A Vernier scale of dimensions appropriate to the analogue scale may be used to allow direct fractional reading of the instrument scale division or as agreed to between the user and the manufacturer.

4.3.3 *Digital Scale*

The resolution shall be considered to be one increment of the last active number of the numerical indicator.

4.3.4 *Variation of Readings*

If the readings fluctuate by more than the value previously calculated for the resolution (with no torque applied to the instrument), the resolution shall be deemed to be equal to half the range of fluctuation.

4.3.5 *Units*

The resolution shall be converted to units of torque.

4.3.6 *Lower Limit of Calibration* (T_{Min})

To ensure that the classification is Consistent with resolution of the torque indicator, a lower limit of calibration shall be determined. The calibration shall not be performed below this lower limit, given by the equation:

$$T_{\text{Min}} = a.r$$

where

r = resolution determined in accordance with **4.3**, and

a has the following values:

1) 4 000 for a class 0.05 torque measuring device;
2) 2 000 for a class 0.1 torque measuring device;
3) 1 000 for a class 0.2 torque measuring device;
4) 400 for a class 0.5 torque measuring device;
5) 200 for a class 1.0 torque measuring device;
6) 100 for a class 2.0 torque measuring device; and
7) 40 for a class 5.0 torque measuring device.

4.4 Number of Calibration Orientation (*see* Annex A)

For classes 0.05 and 0.1, the torque measuring device shall be calibrated in either three different mounting positions, each rotated 120° about the measurement axis, or in four different mounting positions, each rotated 90° about the measurement axis. For all other classes, the measuring device shall be calibrated at a minimum of two different mounting positions at least 90° apart. Where the design or specification of the torque measuring device does not allow it to be rotated, a physical disconnection and reconnection of the reference standard shall be deemed acceptable.

4.5 Preliminary Procedure

4.5.1 *Preliminary Procedure* (*For Mechanical Torque Wrench Tester Scale Type*)

4.5.1.1 Place the torque wrench tester (Scale Type) in an appropriate mounting position as shown in Fig. 4. Take every care so that it can be adjusted and aligned about its principal measuring axis between series as shown in Fig. 4. Any misalignment applied to torque measuring device during the calibration shall be kept as minimum as possible where it is observed that the misalignment applied shall have a significant effect on deflection on torque measuring device then same to be considered as a part of uncertainty.

4.5.1.2 In the arrangement shown in the Fig. 4, there is remote possibility of this effect on measurement calculations. Whatever, the deflection observed in the Fig. 4 can be corrected by means of making the Beam No. 4 (*see* Fig. 4) to horizontal position and correct torque can be applied, get desired results and the instrument can be classified accordingly. This is possible due to provided drive and lifting of weights arrangement as shown. Ensure that there is a minimal misalignment between the reference standard and torque measuring device.

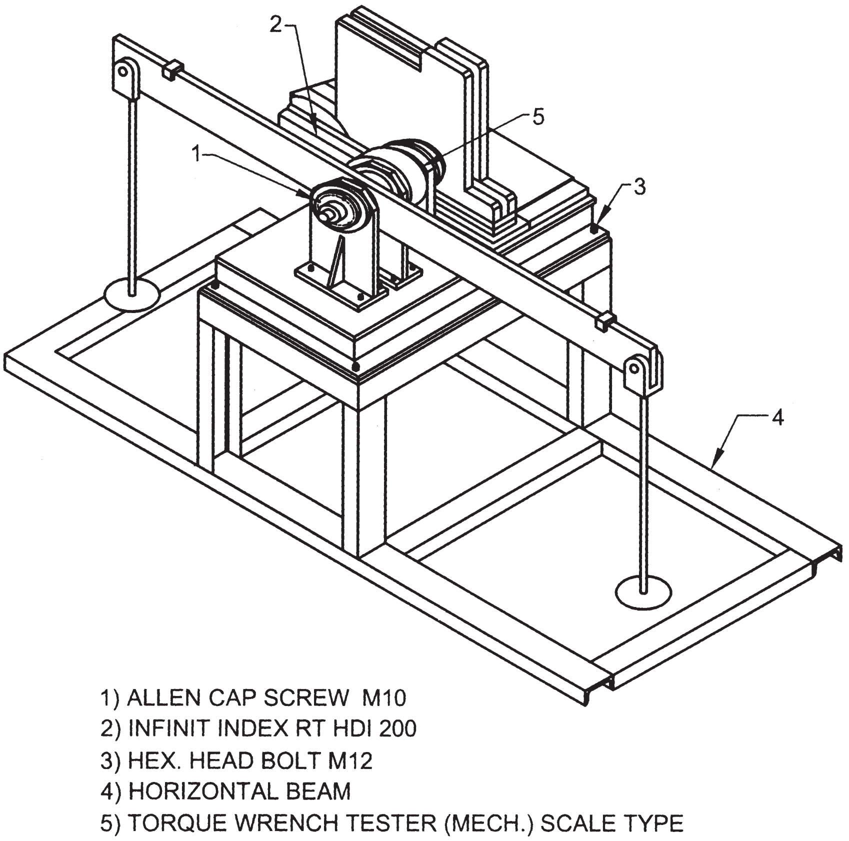

1
2
3
4
5
1) ALLEN CAP SCREW M10
2) INFINIT INDEX RT HDI 200
3) HEX. HEAD BOLT M12
4) HORIZONTAL BEAM
5) TORQUE WRENCH TESTER (MECH.) SCALE TYPE

FIG. 4 TYPICAL TORQUE CALIBRATION SYSTEM FOR MECHANICAL TORQUE TESTER

4.5.2 *Preliminary Procedure for Measuring Electronic Torque Transducer*

4.5.2.1 Place the electronic torque transducer in an appropriate mounting position as shown in Fig. 5. Take every care so that it can be aligned properly about its principal measuring axis between series. Any bending applied to the torque measuring device/transducer during the calibration should be as minimum as possible. Where it is felt that the bending applied could have a significant effect on a deflection of torque measuring device, this should be considered as a part of uncertainty. In the arrangement shown in the Fig. 5, there is less possibility of this effect on measurements/calibration.

4.5.2.2 Whatever the deflection observed in the arrangement can be corrected by means of making the Beam No. 9 (*see* Fig. 5) to the horizontal position and correct torque can be applied and get desired results and measuring device can be classified accordingly. This is possible due to gear box provided at the back of the arrangement and also living of beam mechanism. Ensure that there is a minimum misalignment between the referenda standard and torque measuring device/torque transducer.

4.5.2.3 In the same way hydraulic torque measuring devices can be calibrated by making arrangement. Procedure may be same for calibration.

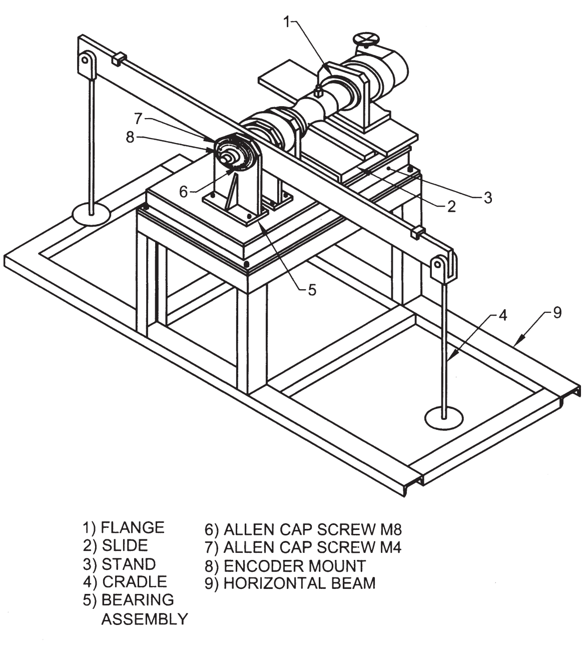


FIG.5 TYPICAL TORQUE CALIBRATION SYSTEM FOR TORQUE TRANSDUCERS

4.5.3 *Temperature Consideration*

4.5.3.1 Where the torque measuring device is electrical, connect the torque measuring device, indicator, switchboxes, interfaces, etc, using the associated electrical cables. Switch on and allow to warm-up for the period stated in the manufacturer's handbook. In the absence of any recommendation energize the system for at least 15 min.

4.5.3.2 Position a thermometer close to the calibration beam or reference torque measuring device and the torque measuring device to be calibrated. Allow the torque measuring device and all relevant parts of the calibration equipment to attain a stable temperature, record the temperature at the beginning and end of each measurement series.

4.5.3.3 Calibrate the torque measuring device at a temperature in the range of 18°C to 28°C. The temperature shall not vary by more than ±1°C throughout a measurement series.

4.5.4 *Indicator Set-up*

4.5.4.1 Carry out checks and setting of the indicator in accordance with the manufacturer's handbook. Select the unit of measurement, for example, Nm, divisions.

4.5.4.2 Where a voltage measuring device is to be used as the indicator, carry out checks and settings in accordance with the manufacturer's handbook. Select the appropriate measuring range, namely V, mV or µV.

4.5.5 *Preloading Procedure*

4.5.5.1 Before any calibration or recalibration, preload the torque measuring device and associated connection components in the appropriate loading direction (that is clockwise or anti-clockwise direction) a minimum of three times in succession to the maximum applied torque of the device. Maintain each preload for a period of between 1 min and 1.5 min. The interval between successive application and removal of preloads shall be as uniform as possible.

4.5.5.2 Where the torque measuring device is to be calibrated in both clockwise and anti-clockwise loading direction, preload the torque measuring device for a minimum of three times before the commencement of calibration.

5 CALIBRATION PROCEDURE

5.1 Selection of Calibration Torques

5.1.1 Select a series of at least five approximately equally spaced, increasing values of torque from 20 percent to 100 percent of maximum applied torque.

5.1.2 If the calibration is required to be made below 20 percent then torque steps of 10 percent, 5 percent and 2 percent of maximum applied torque may additionally be used, provided that they are greater than the calculated lower limit of the calibration range.

5.1.3 Where the use of a torque measuring device that both increasing and decreasing value of torque are measured, select a single series of decreasing values in accordance with **5.1.1** for application at the end of the last series of increasing torques.

5.1.4 An increasing torque shall always be applied in a direction from a lower value of torque. A decreasing torque shall always be applied in a direction from a higher value of torque.

NOTE — Where a reference torque measuring device has been calibrated with both increasing and decreasing value of torque, it may be used to determine torque in both of these modes.

5.2 Application of Calibration Torques

5.2.1 Calibration in one of the following:

a) Clockwise or anti-clockwise direction (*see* **5.2.2**); or
b) In both clockwise and anti-clockwise direction (*see* **5.2.8**).

5.2.2 After the preloading procedure (*see* **4.6.4**), apply two series of increasing torque in clockwise or anti-clockwise direction, as required, to the torque measuring device without change of the mounting position. The indicator reading may be tare to zero at the beginning of each measurement series.

5.2.3 Record the readings of the indicator with zero torque applied to the torque measuring device before and after each application of a series of torques.

5.2.4 The interval between successive application and removal of torques shall be as uniform as possible. Record the reading of the indicator no less than 30 s after each application or removal of torque. For the determination of relative residual deflection, record the residual deflection reading no less than 30 s after the torque is completely removed.

5.2.5 Disturb and remount the torque measuring device in accordance with **4.1**. After reconnection, preload the torque measuring device once to maximum applied torque then apply a further series of increasing torque.

5.2.6 Repeat **5.2.5** until torques has been applied at all required orientations.

5.2.7 Where relative reversibility is required, a single series of decreasing values shall be applied at the end of the last series of increasing torque.

5.2.8 Where the torque measuring device is required to be calibrated for both clockwise and anti-clockwise torques, repeat the procedure given in **5.2.2** to **5.2.7** for the opposite direction.

6 CALCULATIONS OF RESULTS

6.1 Determination of Deflection (*d*)

Algebraically subtract the indicator reading for the initial zero torque from the indicated reading for each applied torque and the final zero torque in the measurement series.

NOTE — The unit of indicator reading is in units of torque, for example Nm, or, where a voltage measuring device is used, in units of volt, for example V, mV or µV.

6.2 Determination of Relative Repeatability (R_1)

6.2.1 For each value of increasing torque applies in a clockwise or anti-clockwise direction; calculate the repeatability of the deflection for the first and second series of applied torque.

6.2.2 Express the repeatability as a percentage of the mean deflection dR_1 for the first and second application of the given torque, using equations (1) and (2):

$$dR_1 = (d_1+d_2)/2 \qquad \ldots(1)$$

where

dR_1 = mean deflection for a given torque;
d_1 and d_2 = deflections for a given increasing torque (series 1 and 2)

$$R_1 = d_1 – d_2/dR_1 \times 100 \qquad \ldots(2)$$

where

R_1 = relative repeatability.

6.3 Determination of Relative Reproducibility (R_2)

6.3.1 For each value of increasing torque applied in a clockwise or anti-clockwise, calculate the reproducibility of the deflection for the series of applied torque.

6.3.2 The reproducibility shall be expressed as a percentage of the mean deflection dR_2 for the applications of the given torque, using equations (3) (4) or (5), as applicable, and (6).

a) For two orientations:

$$dR_2 = (d_1+d_3)/2 \qquad \ldots(3)$$

b) For three orientations:

$$dR_2 = (d_1+d_3+d_4)/3 \qquad \ldots(4)$$

c) For four orientations:

$$dR_2 = (d_1+d_3+d_4+d_5)/4 \qquad \ldots(5)$$

where

dR_2 = mean deflection calculated from the first series at each orientation; d_1, d_3, d_4 and d_5 are the deflections for a given increasing torque from the first series at orientation:

$$R_2 = [(d_{\mathrm{Max}} – d_{\mathrm{Min}})/dR_2] \times 100 \qquad \ldots(6)$$

where

d_{Max} = maximum deflection for a given increasing toque from all series; and
d_{Min} = maximum deflection for a given increasing toque from all series.

6.4 Determination of Relative Error of Interpolation (E_{it})

6.4.1 The error of interpolation shall only be determined where the deflection is expressed in units other than those of torque (for example units of V, mV).

6.4.2 Compute a 'best fit' first, second or third order polynomial equation relating the mean deflection to the increasing calibration torques. Equal weighting shall be given to all points. Compute the polynomial series such that the sum of the squares of the residuals, that is, the departure of the actual calibration reading from the computed values given by the equation, is a minimum.

6.4.3 At each increasing calibration torque, calculate the residual as a percentage of the compound deflection for the given torque, using equation (7):

$$E_{\mathrm{it}} = [(dR_2 – d_{\mathrm{comp}})/d_{\mathrm{comp}}] \times 100 \qquad \ldots(7)$$

where

E_{it} = relative error of interpolation, and
d_{comp} = computed deflection for the given increasing torque.

6.5 Determination of Relative Residual Deflection (R_{o})

Determine the maximum residual deflection obtained from the applied series of torque and express this as a percentage of the mean deflection at maximum applied torque using the equation (8):

$$R_o = (d_{\mathrm{oMax}}/dR_{\mathrm{2Max}}) \times 100 \qquad \ldots(8)$$

where

R_{o} = residual deflection
d_{oMax} = maximum residual deflection, and
dR_{2Max} = mean deflection at maximum applied torque.

6.6 Determination of Relative Reversibility (R_3)

Express the relative reversibility as a percentage of the deflection for the given torque from the last applied series of torques, using equation (9):

$$R_3 = [(d_{\mathrm{dec}} - d_{\mathrm{inc}})/d_{\mathrm{inc}}] \times 100 \qquad \ldots(9)$$

where

R_3 = relative reversibility,
d_{dec} = deflection for the application of the corresponding decreasing torque, and
d_{inc} = deflection for the application of the last series of a given increasing torque.

6.7 Determination of Relative Error Indication

6.7.1 The relative error of indication shall only be determined where the deflection is expressed in units of torque.

6.7.2 Calculate for each value of increasing torque applied in clockwise or anti-clockwise direction the error of indication for the given torque. Calculate the mean deflection (dR_2) for the applications of the given torque and express the relative error of indication as a percentage of the true value of torque (T_a), for example, the accepted value of the applied calibration torque, using equation 10:

$$E_i = [(dR_2 - T_a)T_a] \times 100 \qquad \ldots(10)$$

where

E_i = relative error of indication,

dR_2 = mean deflection calculated from the first series at each orientation, and

T_a = given increasing calibration torque.

7 CLASSIFICATION OF TORQUE MEASURING DEVICES

7.1 Procedures for Classification

7.1.1 *General*

7.1.1.1 Where the deflection is expressed in units of torque, and increasing torques has been applied, the classification and range of that classification shall be determined for the following parameters:

a) Repeatability;
b) Reproducibility;
c) Residual deflection; and
d) Error of indication.

Where decreasing torques has also been applied, the classification and its range for the relative reversibility shall also be determined in additions to these parameters. If deflection is expressed in units other than those of torque, determine the error of interpolation instead of error of indication.

7.1.1.2 Uncertainties of measurement are not used to determine the classification.

7.1.2 *Determination of Classification and its Range*

7.1.2.1 To permit an analysis of the results of the calibration, a target classification shall be selected consistent with the intended use of the torque measuring device.

7.1.2.2 At each calibration torque from the maximum applied torque to be calibrated downwards, the values of error calculated for each parameter being classified shall not exceed the value given for the selected classification in the appropriate column of Table 2. The classification shall cease to apply at the first calibration torque where the limit for the selected classification is exceeded. The minimum range of measurement for a selected classification shall be 20 percent to 100 percent of maximum applied torque.

7.1.2.3 If conformity with **7.1.2.2** in respect of all the parameters for which the classification is being sought is achieved, the selected classification shall be deemed to have been met. If the range of one or more of the parameters does not meet the requirements of **7.1.2.2**, then the analysis shall be repeated to determine conformance to a lower classifications.

NOTES

1 Where calibration torques have been applied below 20 percent of minimum applied torque and all of the results meet the requirements of **6.1.2.2** then the range of classification of the selected classification can be extended.

2 A second classification of lower class and of an extended range can be awarded provided that all of the requirements of **6.1.2.2** are met in respect of the lower class.

For example:

a) Class 1.0: From 100 Nm down to 20 Nm
b) Class 2.0: From 100 Nm down to 5 Nm

Table 2 Criteria for Classification of Torque Measuring Devices

(*Clause* 7.1.2.2)

Sl No.	**Class**	**Permissible Value** Percent					
		R_1	R_2	E_{it}	R_o	R_3	E_i
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	0.05	± 0.025	± 0.05	± 0.025	± 0.01	± 0.062	± 0.025
ii)	0.1	± 0.05	± 0.10	± 0.05	± 0.02	± 0.125	± 0.05
iii)	0.2	± 0.10	± 0.20	± 0.10	± 0.04	± 0.250	± 0.10
iv)	0.5	± 0.25	± 0.50	± 0.25	± 0.10	± 0.625	± 0.25
v)	1.0	± 0.50	± 1.00	± 0.50	± 0.20	± 1.250	± 0.50
vi)	2.0	± 1.00	± 2.00	± 1.00	± 0.40	± 2.500	± 1.00
vii)	5.0	± 2.50	± 5.00	± 2.50	± 1.00	± 6.250	± 2.50

8 CALIBRATION CERTIFICATE

8.1 General

When the torque measuring device has satisfied the requirement specified in **4 to 7**, a certificate shall be issued stating at least the following:

a) Date of the issue of this certificate, which shall also be identified by a unique reference.
b) Date of calibration.
c) Serial numbers of the torque measuring device and, where appropriate, any mechanical fittings and electrical cables.

d) A brief description of the calibration method and the type of calibration equipment used, including the uncertainty of measurement of the applied calibration torque.

e) A reference to this standard as a basis of test.

f) Range and loading mode of torque over which the torque measuring device conforms to the requirements specified in **4** to **7**, for a given classification.

g) Where the units of deflections expressed in units of torque it shall be stated that the device conforms to the parameters of repeatability, reproducibility, relative residual deflection and error of indicator reading. Where reversibility has been determined and classified, this shall also be stated.

h) Where the unit of deflection is expressed in units of other than those of torque it shall be stated that device conforms to the parameters of repeatability, reproducibility, relative residual deflection and error of interpolation. The degree of the equation determined and the coefficients obtained shall also be stated. Where reversibility has been determined and classified this shall also be stated.

j) The uncertainty of measurement for the given calibration value (*see* Annex B).

k) The average temperature and its range of variation or the maximum and minimum temperature recorded of the torque measuring device during the calibration.

m) A table of the applied torque and corresponding deflection. Where the calibration laboratory supplies the indication device, the uncertainty of measurement of the conditioning devices (including the display, energizing device and cables) can also be included in the calibration certificate.

8.2 Frequency of Calibration

The torque measuring device shall be recalibrated at least every 12 months and whenever, it suffers any damage or has been subject to any repair.

ANNEX A

(*Clause* 4.4)

ORIENTATION DIAGRAMS

A-1 The diagrams given in Fig. 6 to Fig. 11 show examples for the calibration of torque measuring devices.

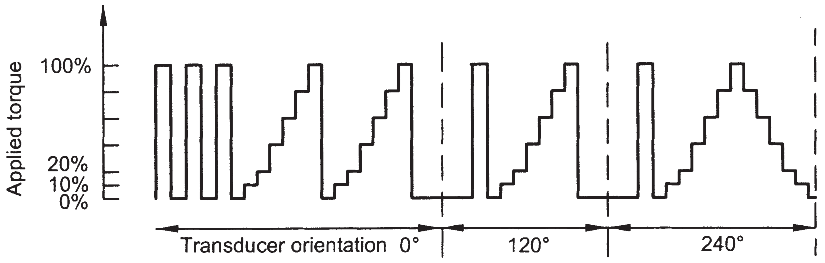


FIG. 6 EXAMPLE OF PRELOADING AND CALIBRATION SEQUENCES FOR A TORQUE MEASURING DEVICE WITH ROUND SHAFT DRIVES, SIX INCREASING AND DECREASING TORQUES, CLASSES 0.05 TO 5.0

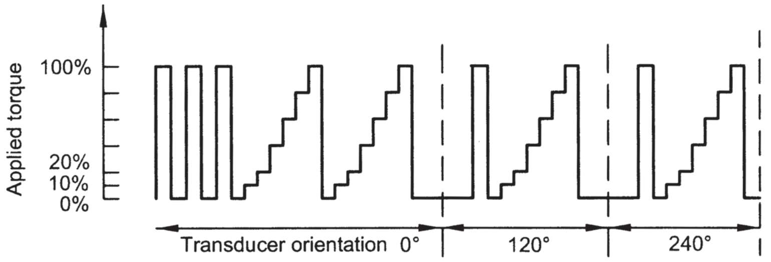


FIG. 7 EXAMPLE OF PRELOADING AND CALIBRATION SEQUENCES FOR A TORQUE MEASURING DEVICE WITH ROUND SHAFT DRIVES, SIX INCREASING TORQUES ONLY, CLASSES 0.05 TO 5.0

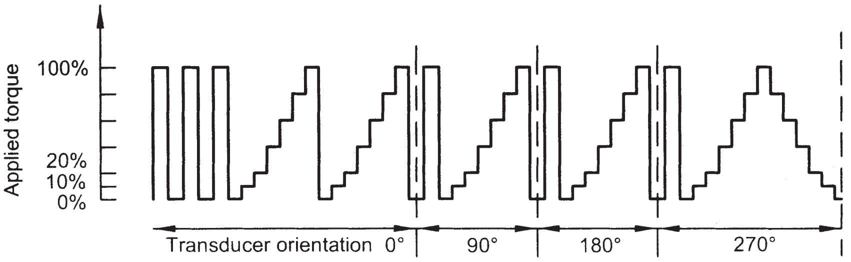


FIG. 8 EXAMPLE OF PRELOADING AND CALIBRATION SEQUENCES FOR A TORQUE MEASURING DEVICE WITH SQUARE DRIVES, SIX INCREASING AND DECREASING TORQUES, CLASSES 0.05 TO 5.0

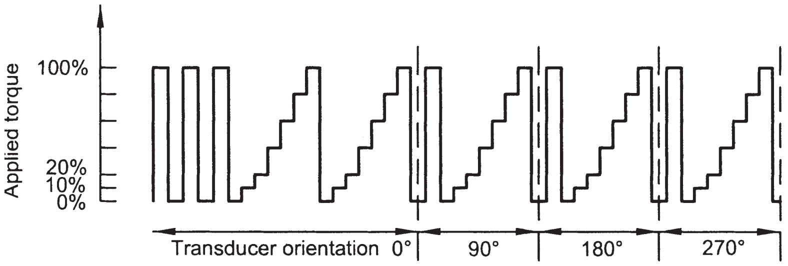


FIG. 9 EXAMPLE OF PRELOADING AND CALIBRATION SEQUENCES FOR A TORQUE MEASURING DEVICE WITH SQUARE DRIVES, SIX INCREASING TORQUES ONLY, CLASSES 0.05 TO 5.0

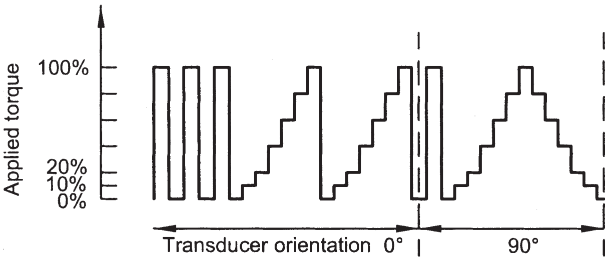


FIG. 10 EXAMPLE OF PRELOADING AND CALIBRATION SEQUENCES FOR A TORQUE MEASURING DEVICE, SIX INCREASING AND DECREASING TORQUES, CLASSES 0.2 TO 5.0.

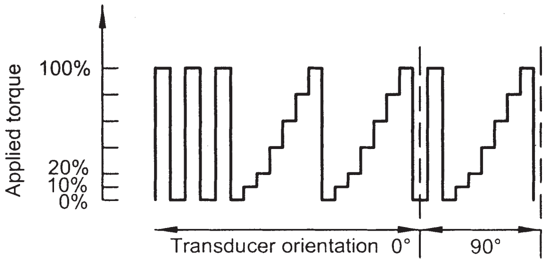


FIG. 11 EXAMPLE OF PRELOADING AND CALIBRATION SEQUENCES FOR A TORQUE MEASURING DEVICE, SIX INCREASING TORQUES ONLY, CLASSES 0.2 TO 5.0

ANNEX B

(*Clause* 8.1)

UNCERTAINTY OF MEASUREMENT

B-1 METHOD EXAMPLE OF DETERMINING UNCERTAINTY OF THE CALIBRATION RESULTS OF THE TORQUE MEASURING DEVICE

B-1.1 Uncertainty of the Calibration Results

B-1.1.1 *General*

For torque measuring devices where the deflection is in torque units, the calibration uncertainty is that of the torque value given by the error of indication when the deflection of the device is a specific torque value calculated from the interpolation equation, at any measured deflection.

At each calibration torque T, a combined standard uncertainty u_c is calculated from the reading obtained during the calibration. These uncertainties are then multiplied by the coverage factor $k = 2$ to give an expanded uncertainty value U.

$$u_c = \sqrt{\sum_{i=}^{n} u_i^2} \text{ and } U = k.u_c$$

All units are expressed as relative values

where

u_1 = standard uncertainty associated with the calibration torque.
u_2 = standard uncertainty associated with the reproducibility of the device.
u_3 = standard uncertainty associated with the repeatability of the device.
u_4 = standard uncertainty associated with the resolution of indicator.
u_5 = standard uncertainty associated with the residual deflection of the device.
u_6 = standard uncertainty associated with the temperature of the device.
u_7 = standard uncertainty associated with the error of interpolation when units other than those of torque are uses (*see* **6.4**).
u_8 = standard uncertainty associated with the reversibility of the device.
n = number uncertainty contributions u_i

B-1.2 Calculation of Calibration Torque Uncertainty (u_1)

u_1 is the standard uncertainty associated with the torque generated by the calibration machine. This value should be obtained from the calibration certificate of the calibration machine.

B-1.3 Calculation of Reproducibility Uncertainty (u_2)

u_2 is the standard deviation associated with the population of incremental deflections obtained during the calibrations:

$$u_2 = 0.5\ R_2/\ \sqrt{2}$$

where

R_2 = relative reproducibility.

B-1.4 Calculation of Repeatability Uncertainty (u_3)

u_3 is the uncertainty contribution due to the repeatability of the measured deflection. It can be assumed that, at each calibration torque T:

$$u_3 = 0.5\ R_1/\sqrt{3}$$

B-1.5 Calculation of Resolution Uncertainty (u_4)

Each deflection value is calculated from two readings (The reading with an applied torque minus the reading at zero torque). Because of this, the resolution of the indicator needs to be included twice as a single triangular distribution with a standard uncertainty of $r/\sqrt{12}$, where r is the resolution expressed as a relative value. Where it is possible to tare the initial reading of each series to zero, a single rectangular distribution with a standard uncertainty of r can be used:

$$u_4 = r/\sqrt{6}$$

B-1.6 Calculation of Residual Deflection Uncertainty(u_5)

u_5 is the uncertainty component due to the variation in the relative residual deflection:

$$u_5 = 0.5\ R_o/\sqrt{3}$$

B-1.7 Calculation of Temperature Uncertainty (u_6)

u_6 is the contribution due to the variation of temperature thought-out the calibration, together with the uncertainty in the measurement of the temperature. The sensitivity of the device to temperature can be determined using equation:

$$u_6 = k.\Delta t\ /2\sqrt{3}$$

where

k = device's relative temperature coefficient expressed as a percentage of maximum applied torque per degree Celsius, derived either by tests or from the manufactures specification.

Δt = calibration temperature range, allowing for the uncertainty in the measurement of the temperature.

NOTE — The temperature coefficient to be used is that of sensitivity, not of zero.

B-1.8 Calculation of Error of Interpolation Uncertainty (u_7)

u_7 is the uncertainty contribution due to the relative error of interpolation:

$$u_7 = 0.5\ E_{it}/\sqrt{6}$$

B-1.9 Calculation of Reversibility Uncertainty (u_8)

u_8 is the uncertainty component due to the relative reversibility R_3:

$$u_8 = 0.5\ R_3/\sqrt{3}$$

B-1.10 Calculation of Combined Standard Uncertainty (u_c)

For each calibration torque, calculate the combined standard uncertainty u_c by combining the individual standard uncertainties in quadrature.

B-1.11 Calculation of Expanded Uncertainty (U)

$$u_c = \sqrt{\sum_{i=1}^{n} u_i^2} \text{ and } U = k.u_c$$

where $k = 2$.

B-2 OVERALL ACCURACY OF THE DEVICE (O_a)

The overall accuracy O_a of the device can be obtained by combining the classification accuracy with the expanded uncertainty in quadrature:

$$O_a = [(E_i/\sqrt{3})^2 + (U/2)^2]^{1/2}$$

The overall accuracy O_a of the device is then multiplied by the coverage factor $k = 2$ to give an expanded uncertainty value U_{o_a}. The classification accuracy is obtained from the error of indication E_i column in Table 2.

B-3 WORKED EXAMPLES OF CALCULATION OF UNCERTAINTY OF THE CALIBRATION RESULTS OF THE TORQUE MEASURING DEVICE CALIBRATION IN TORQUE UNITS (INCREASING TORQUES ONLY)

B-3.1 Obtain Raw Data

B-3.2 Calculate Parameters: Mean Indicated Output, Relative Repeatability, Relative Reproducibility, Relative Error of Indication and Relative Residual Deflection.

B-3.3 Classify Device Using Table 2

B-3.4 Calculate Uncertainties

B-3.4.1 *Obtain Applied Torque Uncertainty* (u_1)

B-3.4.2 *Calculate Reproducibility* (u_2)

B-3.4.3 *Calculate Repeatability* (u_3)

B-3.4.4 *Calculate Resolution* (u_4)

B-3.4.5 *Calculate Residual Zero Deflection* (u_5)

B-3 .4.6 *Calculate Temperature* (u_6)

B-3.4.7 *Calculate the Combined Uncertainty* (u_c)

B-3 .4.8 *Calculate the Expanded Uncertainty* (U)

Table 3 Worked Example in Torque Units : 500 Nm Torque Measuring Device Clockwise Torque, Increasing Series Only (Continued)

(*Clause* B-3)

Sl No.	Applied Torque N.m	Raw Data			Mean Indicated Deflection
		1	2	3 After Resetting	
(1)	(2)	(3)	(4)	(5)	(6)
i)	0	0.0	0.0	0.0	0.0
ii)	100	100.4	100.3	100.4	100.4
iii)	200	200.8	200.9	200.8	200.8
iv)	300	300.8	300.9	300.8	300.8
v)	400	401.2	401.3	401.2	401.2
vi)	500	501.6	501.5	501.6	501.6
vii)	0	0.0	0.1	0.1	

Table 3 Worked Example in Torque Units : 500 Nm Torque Measuring Device Clockwise Torque, Increasing Series Only (Continued)

Applied Torque Nm	Relative Repeatability R_1 %	Relative Reproducibility R_2 %	Relative Error of Indication E_i %	Relative Residual Deflection R_o %
100	0.10	0.00	0.40	0.1
200	0.05	0.00	0.45	
300	0.03	0.00	0.26	
400	0.02	0.00	0.30	
500	0.02	0.00	0.32	

Table 3 Worked Example in Torque Units : 500 Nm Torque Measuring Device Clockwise Torque, Increasing Series Only (Continued)

Applied Torque Nm	Classification				
	Relative Repeatability R_1	Relative Reproducibility R_2	Relative Error of Indication E_i	Relative Residual Deflection R_o	Lower Limit of Calibration T_{Min}
100	0.2	0.05	2.0	0.5	0.2
200	0.1	0.05	2.0		0.1
300	0.1	0.05	2.0		0.5
400	0.05	0.05	2.0		0.05
500	0.05	0.05	2.0		0.05

B-4 WORKED EXAMPLE OF CALCULATION OF UNCERTAINTY OF THE CALIBRATION RESULT OF THE TORQUE MEASURING DEVICE CALIBRATED IN UNITS OTHER THAN TORQUE (INCREASING AND DECREASING TORQUES) (*See* Tables 5 and 6)

B-4.1 Obtain Raw Data

B-4.2 Calculate Parameter: Mean Indicated Output, Repeatability, Relative Reproducibility, Relative Error of Interpolation, Relative Residual Deflection and Relative Error of Reversibility

B-4.3 Classify Device Using Table 2

B-4.4 Calculate Uncertainties

B-4.4.1 *Obtain Applied Torque Uncertainty* (u_1)

B-4.4.2 *Calculate Reproducibility* (u_2)

B-4.4.3 *Calculate Repeatability* (u_3)

B-4.4.4 *Calculate Resolution* (u_4)

B-4.4.5 *Calculate Residual Zero Deflection* (u_5)

B-4.4.6 *Calculate Temperature* (u_6)

B-4.4.7 *Calculate Error of Interpolation* (u_7)

B-4.4.8 *Calculate Error of Reversibility* (u_8)

B-4.4.9 *Calculate the Combined Uncertainty* (u_c)

B-4.4.10 *Calculate the Expanded Uncertainty* (U)

Table 4 Calculation Uncertainties

(*Clause* B-3)

Sl No.	**Applied Torque Nm**	**Applied Torque** u_1 **Taken from the Calibration Certificate of the Calibration Machine**		**Reproducibility** $u_2 = 0.5\ R_2 / \sqrt{2}$		**Repeatability** $u_3 = 0.5\ R_1 / \sqrt{3}$		**Resolution** $u_4 = r / \sqrt{6}$		**Residual Deflection** $u_5 = 0.5 R_0 / \sqrt{3}$		**Temperature** $u_6 = k.\Delta t/2\ \sqrt{3}$		**Combined Uncertainty** $u_c = \sqrt{\sum_{i=1}^{n} u_i^2}$	**Expanded Uncertainty** $(k = 2)$ $U = k.u_c$
		Value Percent	Uncertainty Percent	Value Percent	Uncertainty Percent	Value Percent	Uncertainty Percent	Value Percent	Uncertainty Percent	Value Percent	Uncertainty Percent	Value Percent	Uncertainty Percent	Value Percent	Uncertainty Percent
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
i)	100	0.020	0.010	0.09	0.03	0.09	0.026	0.4	0.115	—	—	0.015	0.017	0.1204	0.24
ii)	200	0.020	0.010	0.05	0.02	0.05	0.014	0.2	0.06	—	—	0.015	0.017	0.065	0.13
iii)	300	0.020	0.010	0.03	0.02	0.03	0.008	0.13	0.037	—	—	0.015	0.017	0.043	0.086
iv)	400	0.020	0.010	0.03	0.007	0.03	0.005	0.1	0.028	—	—	0.015	0.017	0.035	0.170
v)	500	0.020	0.010	0.02	0.007	0.02	0.005	0.08	0.023	0.4	0.115	0.015	0.017	0.030	0.062

Table 5 Worked Example in ‘m V/V’ : 2 kNm Torque Measuring Device Clockwise Torque, Increasing and Decreasing Series

(*Clause* B-4)

Applied Torque Nm	**Raw Data**				**Mean Indicated Deflection**
	0		120	240	
	1	2	3	4	
0	0.000 000	0.000 000	0.000 000	0.000 000	0.000 000
40	0.026 852	0.026 851	0.026 853	0.026 853	0.026 853
100	0.067 132	0.067 130	0.067 132	0.067 133	0.067 132
200	0.134 272	0.134 268	0.134 274	0.134 271	0.134 272
400	0.268 547	0.268 546	0.268 552	0.268 549	0.268 549
800	0.537 103	0.537 104	0.537 107	0.537 107	0.537 106
1 200	0.805 676	0.805 679	0.805 678	0.805 681	0.805 678
1 600	1.074 266	1.074 268	1.074 267	1.074 270	1.074 268
2 000	1.342 867	1.342 868	1.342 865	1.342 870	1.342 867
1 600				1.074 297	
1 200				0.805 724	
800				0.537 148	
400				0.268 568	
200				0.134 277	
100				0.067 132	
40				0.026 850	
0				-0.000 003	
	- 0.000 008	- 0.000 011	- 0.000 005	- 0.000 003	- 0.000 005

NOTE — Coefficients:

a) For a deflection d (mV/V) the applied torque T (Nm) is calculated thus:

$T = ad+a_2 d^2+a_3 d^3$

a_1 =1489.5325E+ 3

a_2 = – 0.1265E-1

a_3 = –7E-3

b) For a given applied torque T (Nm), the expected deflection d (m V/V) is calculated thus:

$d = b_1 T + b_2 T^2 + b_3 T^3$

b_1 = 6.713516E-4

b_2 =3.827E-11

b_3 = 1.44E-15

Table 5 Worked Example in ‘m V/V’:2 kNm Torque Measuring Device Clockwise Torque, Increasing and Decreasing Series

(*Clause* B-4)

Applied Torque N.m	**Relative Repeatability** R_1	**Relative Reproducibility** R_2	**Relative Error of Interpolation** E_{it} Percent	**Relative Residual Deflection** R_0 Percent	**Relative Reversibility** R_3 Percent	**Relative Repeatability** R_1	**Relative Reproducibility** R_2	**Relative Error of Interpolation** E_{it}	**Relative Residual Deflection** R_0	**Relative Reversibility** R_3	**Lower Limit of Calibration**
0							0.05	0.05		0.05	0.05
40	0.003 7	0.074	- 0.005 4		- 0.001 1	0.05	0.05	0.05		0.05	0.05
100	0.003 0	0.045	- 0.004 8		- 0.000 1	0.05	0.05	0.05		0.05	0.05
200	0.003 0	0.045	- 0.000 4		0.000 4	0.05	0.05	0.05		0.05	0.05
400	0.000 4	0.022	- 0.000 9		0.007	0.05	0.05	0.05		0.05	0.05
800	- 0.000 2	0.007	- 0.000 2		0.008	0.05	0.05	0.05		0.05	0.05
1 200	- 0.000 4	0.006	- 0.000 1		0.005	0.05	0.05	0.05		0.05	0.05
1 600	- 0.000 2	0.004	- 0.000 1		0.003	0.05	0.05	0.05		0.05	0.05
2 000	- 0.000 1	0.004	- 0.000 0			0.05	0.05	0.05	0.05	0.05	0.05
0				- 0.000 4							

Table 5 Worked Example in ‘m V/V’:2 kNm Torque Measuring Device Clockwise Torque, Increasing and Decreasing Series

(*Clause* B-4)

Applied Torque Nm	**Classification**					
	Relative Repeatability R_1	Relative Reproducibility R_2	Relative Error of Interpolation E_{it}	Relative Residual Deflection R_0	Relative Reversibility R_3	Lower Limit of Calibration
40	0.05	0.05	0.05		0.05	0.05
100	0.05	0.05	0.05		0.05	0.05
200	0.05	0.05	0.05		0.05	0.05
800	0.05	0.05	0.05		0.05	0.05
1 200	0.05	0.05	0.05		0.05	0.05
1 600	0.05	0.05	0.05		0.05	0.05
2 000	0.05	0.05	0.05	0.05	0.05	0.05

Table 6 Uncertainties Calculated in Accordance with Annex B-4

(*Clause* B-4)

Applied Torque Nm	**Uncertainty Contribution**													
	Applied Torque u_1		Reproducibility u_2		Repeatability u_3		Resolution u_4		Residual Deflection u_5		Temperature u_6		Interpolation u_7	
	Taken from the calibration certificate of the calibration machine.		$u_2 = 0.5\ R/2$		$u_3 = 0.5\ R/3$		$u_4 = r/6$		$u_5 = 0.5R/3$		$u_6 = k.\Delta t/2\sqrt{3}$		$u_7 = 0.5\ E_{it}/6$	
	Value Percent	Uncertainty Percent	Value Percent	Uncertainty Percent	Value Percent	Uncertainty Percent	Value Percent	Uncertainty Percent	Value Percent	Uncertainty Percent	Value Percent	Uncertainty Percent	Value Percent	Uncertainty Percent
0														
40	0.002	0.001	0.007 4	0.002 6	0.003 72	0.001 08	0.003 7	0.001 5			0.003	0.000 2	0.005 43	0.001 11
100	0.002	0.001	0.004 5	0.001 6	0.002 98	0.000 86	0.001 5	0.000 6			0.003	0.000 2	0.004 78	0.000 98
200	0.002	0.001	0.004 5	0.001 6	0.002 98	0.000 86	0.000 7	0.000 3			0.003	0.000 2	0.000 35	0.000 07
400	0.002	0.001	0.002 2	0.000 8	0.000 37	0.000 11	0.000 4	0.000 2			0.003	0.000 2	0.000 92	0.000 19
800	0.002	0.001	0.000 7	0.000 3	0.000 19	0.000 05	0.000 2	0.000 1			0.003	0.000 2	0.000 16	0.000 03
1 200	0.002	0.001	0.000 6	0.000 2	0.000 37	0.000 11	0.001	0.000 1			0.003	0.000 2	0.000 15	0.000 03
1 600	0.002	0.001	0.000 4	0.000 1	0.000 19	0.000 05	0.000 0	0.000 0			0.003	0.000 2	0.000 12	0.000 02
2 000	0.002	0.001	0.000 4	0.000 1	0.000 07	0.000 05	0.000 1	0.000 0	-0.000 4	-0.000 1	0.003	0.000 2	0.000 03	0.000 01

Table 6 Uncertainties Calculated in Accordance with Annex B-4 — (*Concluded*)

(*Clause* B-4)

Applied Torque Nm	Reversibility		Combined Uncertainty	Expanded Uncertainty $k = 2$
	$u_8 = 0.5\ R_3 / \sqrt{3}$		$u_c = \sqrt{(u_1^2 + u_2^2 + \ldots + u_n^2)}$	$U = k.u_c$
	Value Percent	Uncertainty	Percent	Percent
0				
40	0.011 2	0.003 2	0.004 8	0.009 6
100	0.001 5	0.000 4	0.002 4	0.004 8
200	0.004 5	0.001 3	0.002 5	0.004 9
400	0.007 1	0.002 0	0.002 4	0.004 9
800	0.007 6	0.002 2	0.002 4	0.004 9
1 200	0.005 3	0.001 5	0.001 9	0.003 7
1 600	0.002 5	0.000 7	0.001 3	0.002 5
2 000	0.000 0	0.000 0	0.001 0	0.002 1

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